Determination of Controller Issued Taxi Clearances

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Research Program Participants

- NASA Ames Research Center
- Sensis Corporation
- Titan Corporation
- USDOT, Volpe Center

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Mitigation of a Problem

- Runway Incursion Causes
  - Pilot deviation while taxiing
  - Operational error by the controller in taxi route assignment
- Research Questions
  - Can a system be developed to digitally classify assigned taxi routes in real-time?
  - What benefits can safety logic systems realize from advanced detection of aircraft taxi routes?

Primary Goal

- Improve safety by providing automatic determination of unusual or unauthorized movement as early as possible
- Eventual integration into safety logic or warning systems should consider controller workload and responsibilities, as well as false alarm mitigation criteria

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ORD Incursion, 1999

Voice Recognition and Contextual Inference

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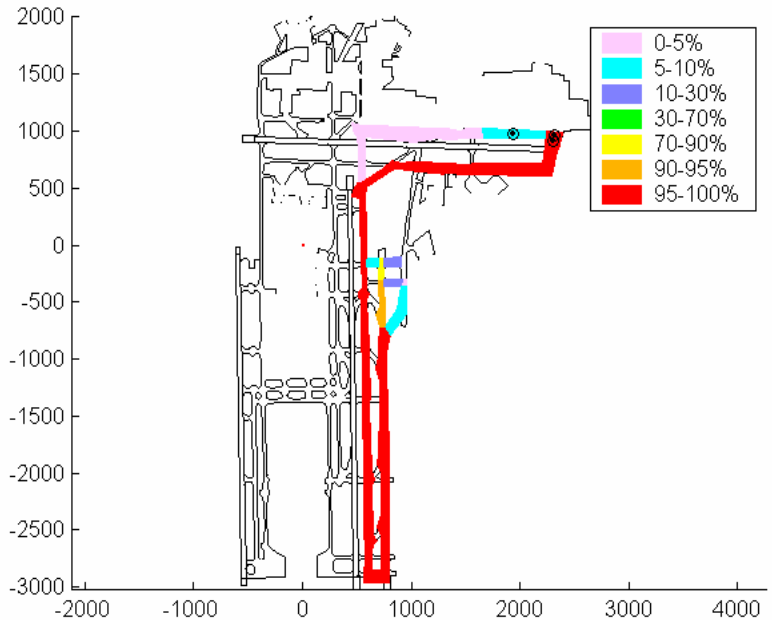
- Question
  - Can voice recognition technology fused with surveillance and flight information (contextual inference) provide accurate information regarding expected taxi route?

Path Frequency Prediction



- Research Approach
  - Evaluate the maturity (e.g., accuracy) of representative, leading edge commercial VR products applied to the airport ground control domain
  - Identify important influencing knowledge. For example, does knowing the airline and certain flight information narrow the likely taxiway selection?
  - Assess the potential for predicting taxi routes from combining VR with context inference knowledge
  - Produce demonstration software using data collected at MEM and DTW

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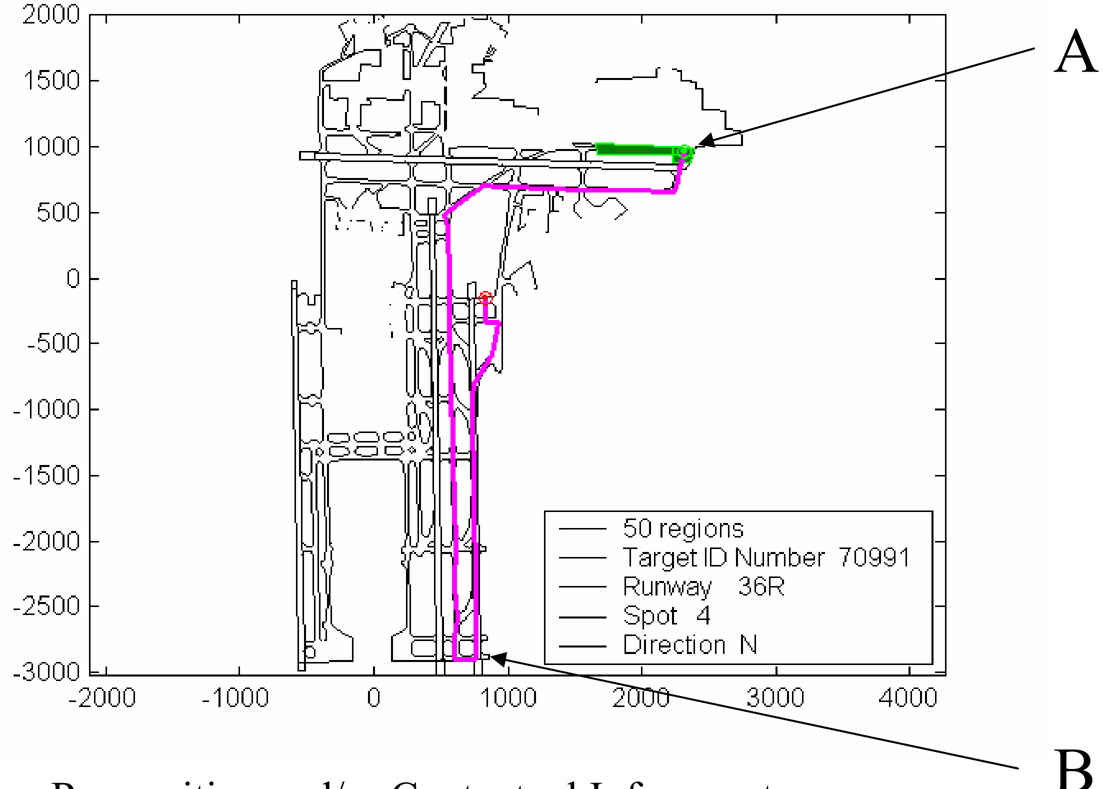
Program Goal



- Use Voice Recognition and/or Contextual Inference to:
  - Given starting point **A**, determine destination, **B**
  - Given starting point **A**, predict path to **B**
  - Given position of aircraft, predict holding times
  - **A** can represent gate for departure or runway for arrival
  - **B** can represent destination runway for departure, destination spot or gate for arrival, or holding point or handoff point for either departure or arrival

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Voice Recognition (VR) Objective

Ground Control Instructions:

"Spirit sixteen eighty nine Metro ground good evening ATIS is echo taxi to runway four right via yankee."

Font Color Code:

- *Flight ID*
- *Taxi information*
- *Destination (runway, handoff or hold points)*
- *Extraneous information*

Objective: Gather ID, taxi, and destination information from voice commands through VR

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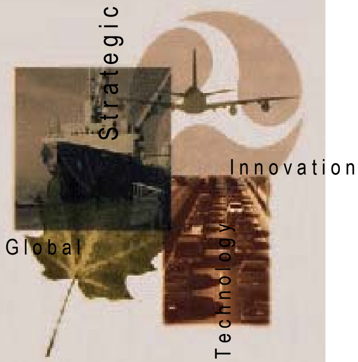
VR Models Studied

Characteristic	*Context Free Grammar*	*Statistical Language Model*
Vocabulary	**Limited vocabulary**	**Broad vocabulary**
Training	**Does not require training**	**Requires a large amount of training data, 1000's of transcribed utterances**
Grammar Structure	**Tightly constrained set of rules including syntax**	**Does not require complex rules, training data defines rules**
Out of Vocabulary	**Low tolerance of words and phrases that are not included in the vocabulary or out of syntax**	**Language models are trained on the speech domain, so all words and phrases are part of the vocabulary**
Commercial Maturity	**Widely used in commercial markets, such as call centers**	**Not widely deployed commercially**



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VR Findings

- Word Error Rates
(Substitution Rate + Deletion Rate + Insertion Rate)
  - Context Free Grammar: 91%
  - Statistical Language Model: 70% - 84%
    - Custom tuning of acoustic models yielded better results
- Major Error Contributors
  - Audio fidelity issues
  - Rapidity of controller / pilot speech
  - Non-standard phraseology makes natural language processing difficult

Silver Lining: Useful information might still be obtained from imperfect recognitions

- *Flight ID*
- *Taxi information*
- *Destination (runway, handoff or hold points)*

VR Findings (continued)

- Context free grammar (CFG)
  - Is not effective in a broad speech domain
  - Experiments demonstrate that it can be effective in an environment where the set of spoken words and phrases are tightly constrained
    - Performed a “What-if” experiment using high quality audio input and constrained vocabulary
      - WERs in the 10%-20% range
    - ATC communications are not expected to be tightly constrained

- Statistical language model (SLM)
  - Has the most promise for a broad speech domain, but requires a large amount of training data
  - More training data produces better results
  - Yielded performance improvement when used with customized acoustic models

VR Future Research

- Investigation of other recognition engine vendors
- Word spotting
  - Spot keywords while discarding all others
- Retuning or customizing acoustic models
  - How effective is this process?
- Improving audio data collection techniques
  - Microphone arrays, modified headsets, etc.
- Distinct engine optimizations for pilot vs. controller?
- Natural Language Processing
  - Once a communication is accurately recognized, how do we parse and use the resulting textual representation?
    - Presents even more challenges if the recognition is incorrect or incomplete

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Contextual Inference (CI) Objectives

- Use Context to determine most likely path and destination for aircraft on the surface.
- Contextual Inference (CI) Sources
  - Flight ID
  - Surveillance (position and velocity)
  - History (surveillance, weather conditions)
  - Geography (airport maps and features)
  - Aircraft characteristics (type, airline, class, weight, etc.)
- Approach: Compare prediction capabilities for various sets of CI information.

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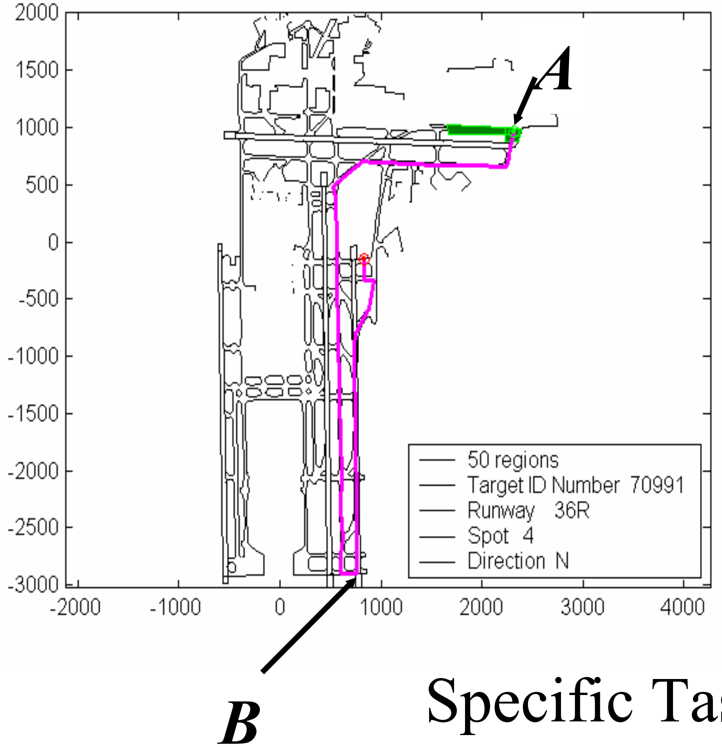
CI Objectives



Specific Tasks

- Taxi Route Prediction (Dep)
- Destination Runway Prediction (Dep)
- Runway Turnoff Prediction (Arr)
- Destination Gate Prediction (Arr)
- Holding Time Analysis

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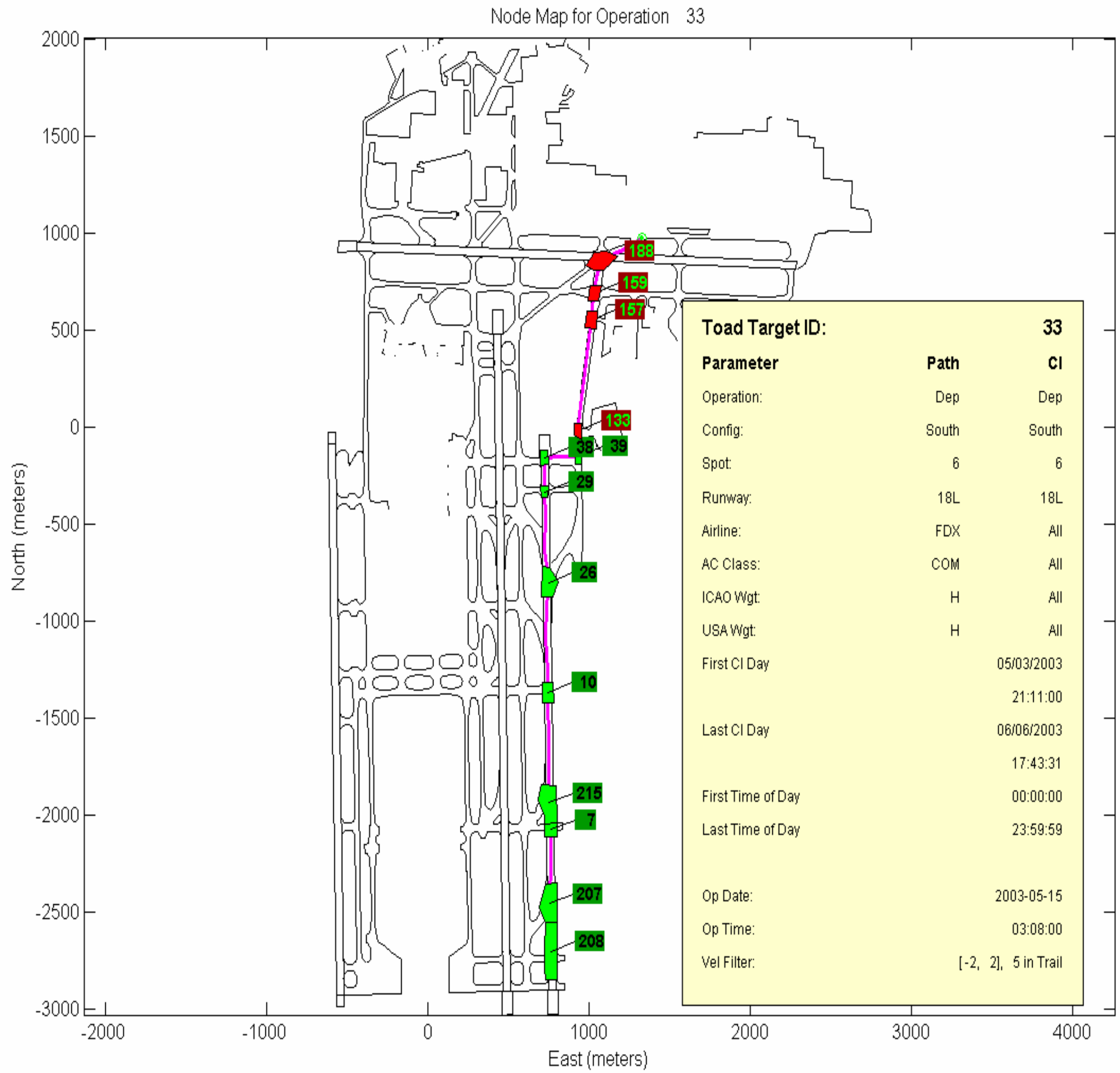
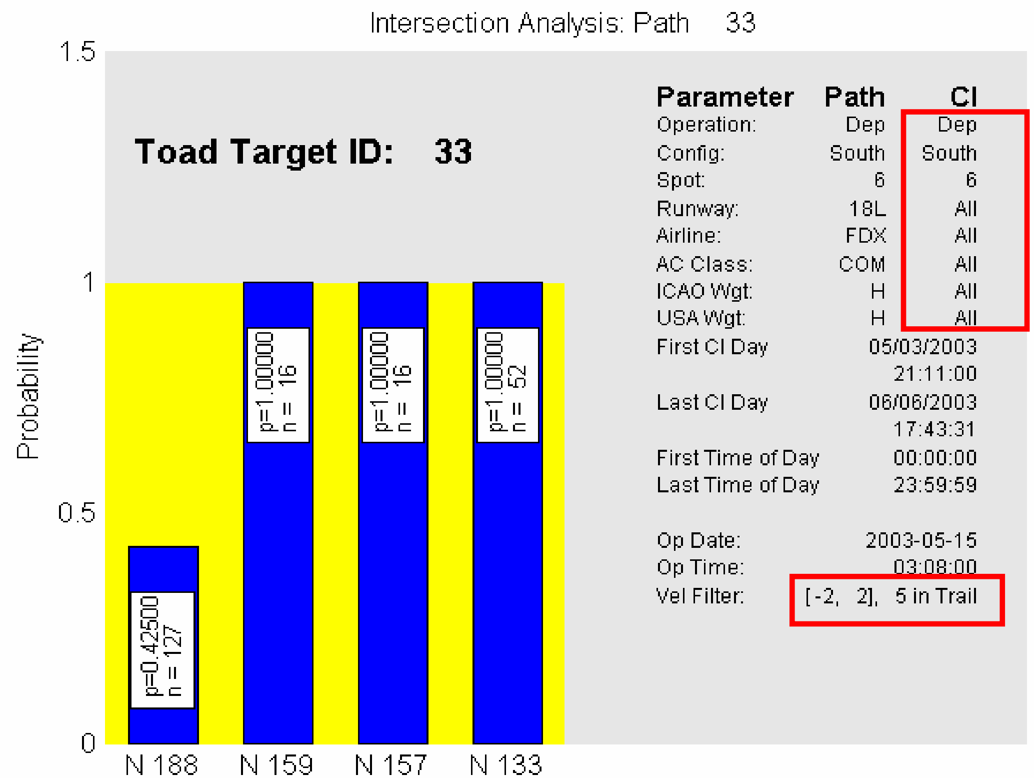
CI Path Nodes



CI Path Prediction – Four Worst Intersections



CI Information

- Path column shows the selected operation
  - Ex, Operation #33
- CI column shows selected conditioning parameters to match against
  - Ex, Departure, South Config, Origin spot 6, Velocity filter
- Bar graph shows percentage of all matching operations that exited nodes in the same direction as the selected operation
  - Ex – 42.5% of matching operations exited node 188 the same way as #33

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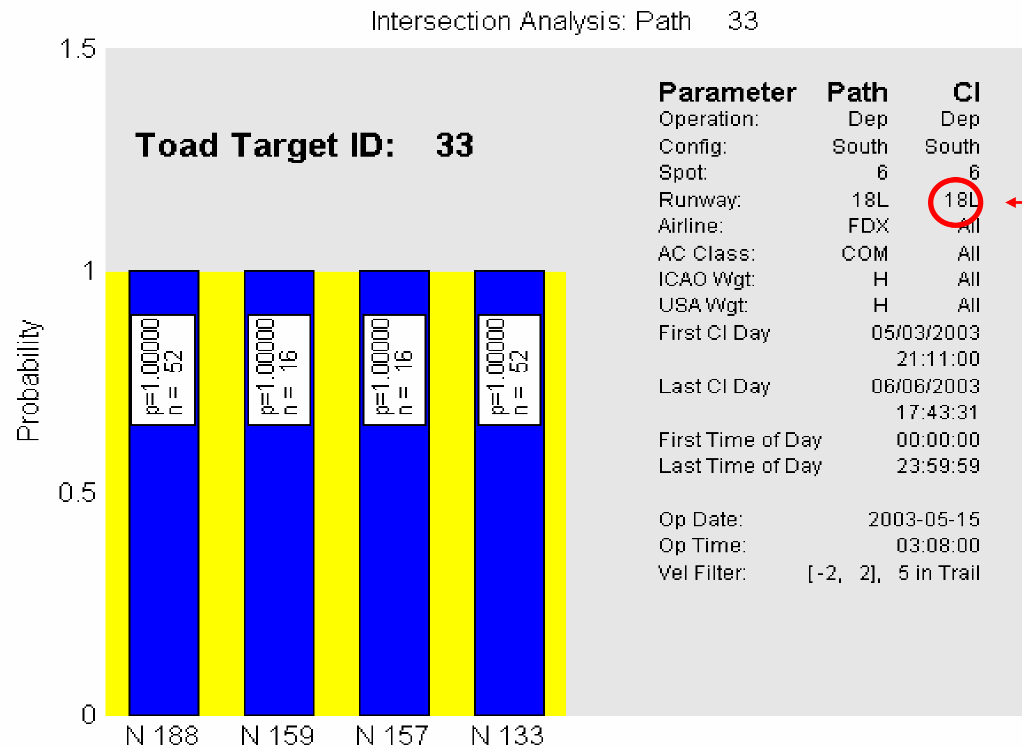
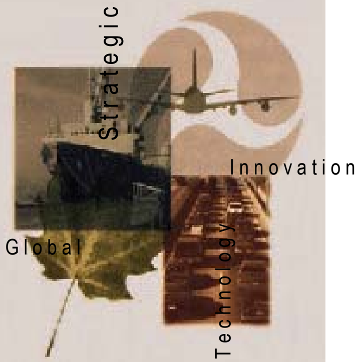
CI Path Prediction – Four Worst Intersections



Destination Runway from VR (Fusion)

- Add another conditioning parameter to match against
  - Ex, Destination runway (maybe obtained through VR)
- Improved prediction
  - Ex – 100% of matching operations exited node 188 the same way as #33
- Implications
  - Shows importance of destination runway for prediction



CI Findings

- (Note: data set investigated was "small," thus these findings will require further investigation to solidify)

- Key Parameters in CI
  - Destination (e.g., runway: can conceivably help predict entire path of departure prior to motion) Fusion w/ VR
  - Velocity (Helps significantly in predicting turn at the time of the turn) Surveillance
  - Airline (Helps by distinguishing gates) Surveillance

- Not-so-important parameters (to date)
  - AC Class
  - Weight Classes

- Require further investigation
  - Time windowing/weighting
  - Surrounding surveillance data

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CI Findings (continued)

- Certain intersections provide turn prediction challenges
  - Further conditioning required (time windowing?)
- Runway prediction improves as path progresses, no CI parameter set yet employed provides robust performance
  - Accuracy in a real-time system would improve as the actual taxi operation progressed
- Spot prediction poorer than runway prediction perhaps because of the number and proximity of spots (more spots in a much tighter region)

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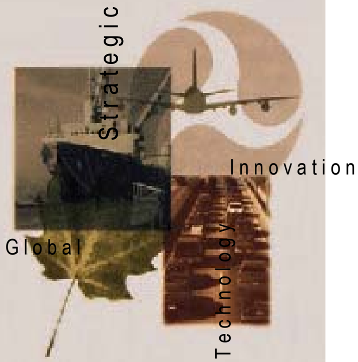
CI Future Research

- Algorithm development
  - Further improvements to statistical algorithms
  - Other predictive technologies such as neural nets might be useful
- Conditioning parameters
  - Further identification of relevant parameters
    - Time of day, week, month, year?
    - Aircraft or activity in vicinity of track?



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VR / CI Fusion

- VR grammars make use of CI – current FIDs (pre-processing fusion)
- CI algorithms benefit from VR destination (pre-processing fusion)
- Post processing fusion requires statistical scoring of VR results and ad-hoc weighting of inputs.

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VR / CI Fusion